

## **A Theoretical Model for Measuring the Influence of Accessibility in Residential Choice Behaviour**

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## **Abstract**

Due to the renewed interest for Integrated Land-use and Transport models, the urge for sound models that describe the behaviour of the agents on the urban markets has grown. A preferred subject of study within this context is the empirical research into the influence of accessibility on the residential choice behaviour of households. However, despite of the effort of several researchers, this relationship seems hard to quantify.

In this paper we present a theoretical design for a discrete choice model of the residential choice of households. From the existing knowledge from a literature review and new insights, we present a new approach for measuring the influence of accessibility on the residential choice process. This theoretical model exists of three main parts, namely: the unique information of households, the arrangement of households into certain destination groups and composing systematic choice sets to estimate a discrete choice model. Within this framework, an important role is set aside for the concept of subjective accessibility, being the individuals perception and utility of accessibility. Finally, we derived a Logit model that is able to combine the simultaneous influence of migration distance and commuting time.

## Introduction

Many researchers have indicated the interaction between land-use and transport as an important knowledge to address policy issues on the field of transport and spatial planning (Miller et al, 1999; Wegener & Fürst, 1999). Recently, more effort has been put in developing more advanced and realistic models that simulate the development of (urban) regions. This regained interest is primarily initiated by three factors, namely: the environmental issues our modern societies have to face, the new methodological insights and the improved computer power of desktop systems. To meet this interest, the Land-Use and Transport interaction models (LUTI-models) have been developed. LUTI-models combine a “traditional” transport with a land-use model. This connection is based on the mutual influence of Land-use and transport (Wegener & Fürst, 1999). Within this line of reasoning it is assumed that the spatial distribution of functions generates activities which result in flows of people and goods. These flows load the transport network and change travel times and therefore accessibility through congestion. Accessibility is then regarded as an attractiveness of locations, and therefore has an impact on land-use.

The theoretical framework of LUTI-models consists mainly of four different urban markets, namely the land market, the real estate market, the housing market and the labour market. On these markets three groups of so-called spatial agents act, i.e. households, firms and governments (Miller et al, 1999; Wegener & Fürst, 1999)

This paper focuses on one specific part of the housing urban market, namely the residential choice behaviour of households and its relationship with accessibility. After all, accessibility is often seen as the link between transport and land-use, and in this case between the transport system and the residential choice of households. However, as we will see from the literature overview in part, this relationship is hard to prove empirically. The paper describes a theoretical framework on how this choice process can be modelled. The framework is partly based on the previous results of theoretical and empirical researches. On the other hand it is inspired by new insights and ideas.

The paper is organised as follows. First we discuss the literature on the impact of accessibility on residential choice. Then we will discuss the moving behaviour of

households from a more demographic point of view. After that issues more related to the theoretical model are brought forward, i.e. the model itself and the data to use. Next, the derivation of a Logit formulation is given, in which the migration distance and commuting time are incorporated. Finally, the paper is rounded up with a short summary and the most important conclusions.

## **The impact of transport on residential choice: literature review**

This part of the paper gives a brief overview of the theoretical and empirical research on the influence of transport on residential choice that has been conducted in the past decennia. It is divided into several components, varying from the classic researches (until the '1970-ies) to the latest progresses in residential choice modelling.

The relationship between transport and land use has always been an appreciated subject of study amongst researchers and policymakers who are active on the overlapping area of mobility and space. The earliest researchers of land use (Weber, 1909; Christaller, 1962; Alonso, 1964; Lowry, 1964) incorporated the direct link between land-use and transport into the descriptions of their (visions on) spatial models. Although through the years more nuanced views have risen, it is still assumed that a large, mutual influence exists (see, for example, the circle of Wegener, 1999). Now, the influence of land-use on transport is, or rather: seems, evident. The spatial distribution of people and activity places generates flows between places in space and time. And although predicting the occupation of a transport network through a transport model is a sinecure, the causal relation is established (Hensher & Button, 2000).

The influence of accessibility on land-use is less obvious, certainly in Western, urbanised areas. Whereas in underdeveloped countries the construction of a new connection often has an almost immediate influence on the surroundings and spatial development, the effect is less distinct in our densely populated and relatively good connected society. This also applies to the influence of accessibility on the residential choice behaviour of households. After all, when a household is looking for a dwelling numerous factors play a role that accessibility almost never comes out as a primary factor of choice. This is acknowledged by several sources, from several fields of study, as we will see in the following paragraphs. They give an overview of the relevant

researches concerning the (empirical) studies on the relationship between accessibility and the residential choice of households.

### **Traditional models (until early '1970-ies)**

In the 19<sup>th</sup> and first half of the 20<sup>th</sup> century, the large western cities had a strong monocentric character. Herein the relation between residential choice and transport was quite evident. One lived in the periphery of the city, from a certain distance to the Central Business District (CBD), which usually was situated in the centre of the town and which formed the concentration of the job potential. The distance between CBD and dwelling depended, roughly, on two factors, namely the available transport mode and the wealth of the household. After all, the property near the CBD was more wanted and therefore more expensive. The classical residential location choice models of Lowry (1964), Alonso (1964), Muth (1969) describe these phenomena.

As the transport techniques improved and transport (especially cars) became less expensive, people were better able to move. That way, the distance between CBD (work location) and periphery (residential location) could increase. This resulted in larger cities and congested networks around them, and eventually, in larger urban regions with multiple centres. On this new situation the traditional models did not apply anymore, so new ways of examining the residential choice of people and households were developed.

### **Quantitative models**

Several researchers have gone into the quantifying the link between residential choice and accessibility. Albeit that they are from different fields (econometrics, (social) geography, civil engineering, urban planning, etc.), they generally use econometric estimating methods to demonstrate the relation. Clark & Van Lierop (1986) have given an overview of the state of the art in modelling residential choice at that time. However, the then available armamentarium is still the basis of most of the (empirical) studies. New techniques like neural networks are only applied scantily (Raju e.a., 1998).

From the literature it shows that the residential choice research is performed in waves. Sometimes this is inspired by new theories, like in the second half of the '70 and the early '80. The last decade new interests have arisen, under influence of stronger

(desktop) computer and new and improved data on residential preferences and moves. The most applied theories are the Random Utility Theory and the Hedonic Price Method.

Both techniques are capable to measure and weigh the (mutual) impact of the attributes of a dwelling. Yet, The Random Utility Theory is specially developed to simulate discrete choices. It is more in line with the perception of choice behaviour, because of the inclusion of uncertainty, which makes the choice probabilistic by nature. The Hedonic Price Method, on the contrary, determines the (deterministic) influence of attributes on the price making of a certain good, whether or not confronted with the supply (in this context: land or dwelling costs). More, general literature on discrete choice modelling can be found in Hensher and Johnson (1981), Ben-Akiva & Lerman (1985) and Train (2003).

#### *Random utility theory (RUT)*

One of the first attempts to apply the RUT on residential choice, is described in McFadden (1978). Despite the fact that this research lacks empirical results, it is one of the first publications about the theoretical application of the then still fairly new discrete choice technique on residential choice. Since then the RUT is applied many times on this research field. However, it appeared hard to measure a significant influence of accessibility. This can either mean that there is no influence or that the modelling approach and/or data used were not adequate. Some examples of attempts with discrete choice model are given below.

The role of “general” accessibility of, for example, labour, people or services seems difficult to quantify in residential choice models. (TIGRIS, 2004; Molin & Timmermans 2002). The relation with commute distance however, is observed several times as an influential factor (Evers, 1990; Weisbrod et al., 1980; Kim et al., 1998, Molin & Timmermans, 2002). Commuting distance has also turned out to be an important independent variable in models that study the behaviour of two-earner households (Timmermans et al., 1992). From this perspective, Rich & Nielsen (2001) have found that in the long run two-earners strive for a certain tuning of working and living location. Moreover, it seems that de valuation of total household travel time has the most influence in rural regions. Waddell (1996) observed that women in general are

more flexible in choosing their working location than men. He thinks that this is probably caused by the larger amount of in-home tasks.

Mostly though, it is found that other attributes like dwelling and neighbourhood have a larger influence than the marginal impact of accessibility (Weisbrod et al, 1980; Molin & Timmermans, 2002). Waddell (1996) even finds a negative, or in other cases insignificant relation between residential location choice and accessibility of jobs and inhabitants. This is probably due to the fact that in this case these measures give more an indication of the preference for the amount of urbanism or urban density. Srour et al. (2002) observe a positive influence of a (logsum) accessibility of jobs on residential location choice. This study, then again, incorporates accessibility measures only, so nothing can be said about substitution effects with other residential choice factors.

New insights look more at a household's unique situation, by taking along personal, spatial relations (e.g. work location, position of the kids' school) and how these relate to daily activity patterns and long-term location choices. From this point of view, Axhausen et al. (2001) have estimated two models on two German cities. From this it appeared that residential location and work place do influence the spatial distribution of activities. Vice versa for the residential choice, only the commute relationship turned out to be a significant. Furthermore, Olatubara (1998) put down this approach in his theoretical model of a "Nestling Approach".

#### *Hedonic Price Method*

A general introduction and first application of the Hedonic Price Method (HPM) to determine the price of a dwelling or a residential location can be found in Rosen (1974). Since then, many follow-ups have been made. Some illustrative examples on measuring the influence of accessibility on the price of a dwelling can be found in Pagliara & Preston (2003) and Srour (2002). The first have studied the consequences of an alteration to the transport system, varying from road pricing to increasing the fuel tax (led to a price increase in the urban area, and a decrease in the periphery) and the influence of a new public transit connection (average increase of 3% in the vicinity of a station). Srour (2002) also found a positive consequence of accessibility on the price of residential property.

### *Other methods*

Next to the econometric methods mentioned above, other ideas were brought forward, to gain more insight into the residential choice behaviour of households. From the perspective of psychoanalysis, Benjamin & Paaswell (1981) carried out a psychometric analysis on a residential choice survey. With this they show that transport and accessibility play only a limited role in relation to the attributes and the costs of the dwelling itself.

A final example of a different approach is the so-called elimination-by-aspects method, which is also discussed in the Clark & van Lierop overview (1986). According to this method, unacceptable alternatives, due to low scoring attributes, are excluded from the choice set. Subsequently, for the remaining alternatives the chance of choice for an alternative is determined by the appreciation attributes. The main advantage of this method is that it approaches the real decision making process better, by means that not all attributes of the alternatives have to be compared. Something a decision maker does not do in real life either. For accessibility Young came up with interesting conclusions, like a strong preference for accessibility of schools and shops, some kind of threshold value for commuting and a limited influence of congestion and nearness of friends. Of course, these aspects of the location all have to compete with the type of dwelling.

### *In conclusion*

Through the years researchers with different approaches tried to quantify the residential location choice, nevertheless with limited success. Many of these studies only regard the residential location, without taking along the characteristics of the dwelling. If these are incorporated, they seem to have a larger impact on the choice behaviour than accessibility. So, if we want to isolate and fathom the influence of accessibility on residential choice, it is important that we take along the other dwelling and location factors in an adequate way. In the next parts of this paper the research approach will be described, using some insights from the literature, like:

- The daily activity pattern and the therewith linked spatial network of a households;
- The elimination of irrelevant alternatives from the choice set by the preferences of the household;

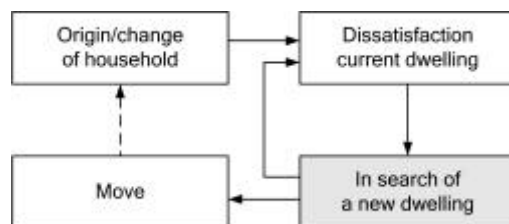


- Applying different levels of spatial scale on which the short- and longer-term decisions of a household take place.

According to Timmermans (2003), to bring the land-use transport interaction modelling to a next level, we have to combine the knowledge from other research fields like demography and transport modelling. This is why we first examine the moving behaviour of households first, before we discuss the actual, theoretical residential model.

## Theoretical model for residential choice

The two driving forces behind move decisions are the life cycle of households and changes in the behaviour on the labour market of one or more members of the household (Robson, 1975). Changes in the household situation are mainly related to relatively short distance moves, the so-called residential mobility. Moves initiated by improving or adjusting the current living situation, are regarded as residential mobility as well. Moves caused by a change of work or study place are called migration. Figure 1 shows a simplified depiction of the cyclic moving process households go through. Rossi (1955) and Clark & Dieleman (1996) discuss this relationship between the life cycle of a household and its residential behaviour, the first publication being a landmark for all later research on this topic.



**Figure 1: Cyclic moving process**

Behind every step lies a sequence of events and motivations, which all affect the residential mobility behaviour. The two most important steps for our research are the searching of a dwelling and the moving to a dwelling, which will be discussed briefly.

### *Searching a dwelling*

When a household starts to search for a new dwelling, it makes a consideration between different attributes of several dwellings. The preferences for a new dwelling differ per

household in terms of price, the location, the size, the living environment and the dwelling type. One can assume that a household strives within this search for a certain type of utility maximisation, or at least satisfaction, given the constraints of the household and the available supply of dwellings (Rouwendaal, 1989). According to the concept of utility maximisation, a household seeks for the dwelling which attributes all meet the preferences in the best way. When this is not possible, simply because such house doesn't exist, substitution behaviour takes place (Hooijmeyer, 1990). The earlier mentioned random utility theory is developed for such issues.

### *Moving*

When the household does not succeed in finding a suitable dwelling (unsuitable here means below a certain minimal amount of utility), the household does not move. It will then wait until a better occasion arises, change its preferences or adapt the current dwelling in such a way that the direct need to move disappears (Priemus, 1984).

If a household does decide to move, an available dwelling is filled up and another one is left behind. The chance that a household finds a suitable dwelling depends of course on the current supply. The most popular dwellings are less available (or occupied fastest), the less popular encounter longer periods of vacancy.

## **Theoretical model for residential choice**

This study focuses on the actual search for a new dwelling. This means that the household has already decided where to move. The conceptual model for this research is already presented more elaborately in Blijie (2004). This section gives only a short summary of the most important features of the model.

Before we explain the new modelling approach for residential choice, it is important to state that it concerns an explanatory model. This means that we try to explain residential choice the best way we can, using all types of historical information and data on past movements. There is a big difference here with a prognosis model, which tries to model future decisions and outcomes for an entire region.

As mentioned in the introduction, the objective of the proposed research is to model the residential choice behaviour of households. This paper focuses on how the role of accessibility can be determined in this choice process. The literature review earlier in

this paper already gave an overview of the research previously conducted. This part uses that knowledge to develop a new, theoretical approach.

First it is necessary to clarify some of the definitions used in the research objective. By residential choice we mean the choice for a dwelling, which is situated on a location. This in contrary to many of the researches observed that merely look either at the location or the dwelling itself. Secondly, the concept of households as a decision unit needs some explanation. This study does not investigate the internal decision making process of households. This means that not the individual choice behaviour is regarded, but the behaviour of certain types of (aggregated) households, like living alone, living together, and living together without kids. Household specific characteristics as the number of kids, workers or cars in a household can, of course, be taken along in the model description. It is also possible to classify a household into certain destination groups, which we will discuss later. Finally, accessibility is regarded in a very broad way. This means that we distinguish potential accessibilities like the number of jobs within half an hour, the distance to the closest primary school or the commuting travel time.

The proposed model to distillate the role of accessibility in the residential location choice behaviour of households is based on the random utility theory. This theory provides a sound basis for modelling discrete choice behaviour, as choosing a new dwelling is, and is able to analyse the tradeoffs between preferences of decision makers. The theory was first applied by McFadden in 1972 in his Multinomial Logit approach and later on used in many issues that concern discrete choices. Because of the strict regulations of the Logit model, many variations were made, each applicable for a certain situation. More on the theoretical background on discrete choice modelling can be found in Train (2003). McFadden himself, as mentioned in the literature review, already proposed a Nested Logit Modelling approach for the residential location choice in 1978.

The theoretical model consists of three steps: Arrangement of households into specific groups, systematic choice set generation and a disaggregated discrete choice model. Each of the parts will be discussed briefly below.

### *Specific groups of households.*

When combining traditional household characteristics (age, size, income, etc.) to form aggregated groups, it could result in many group types. With this the risk exists that there are not enough records to estimate your model on. Therefore, we believe that fewer groups, formed on both traditional and non-traditional characteristics could be beneficial. By non-traditional we mean preferences and behavioural aspects for the specific purpose, namely modelling the residential choice. Within these groups a mutual behaviour in terms of residential preferences, mobility behaviour and such should exist. It is also possible to make a classification based on lifestyle features.

This approach is quite new, and therefore only a small amount of work has been published (Brun & Fagnini, 1994; Axhausen & König, 2001; Krizek & Waddell 2002; Pinkster & Van Kempen). Although these researches use a different approach and different variables, they all come to the conclusion that incorporating lifestyle factors in residential choice modelling could be beneficial, but never replace the traditional factors.

### *Systematic choice set generation*

According to McFadden (1978), the choice set necessary for estimating a discrete choice model, can be drawn randomly from the universal set of opportunities, instead of using the entire range. This should give the same model outcomes and is preferable, since it simplifies the estimating procedure. However, drawing a random sample from the universal set of alternatives is not very reasonable. After all, if a household searches for a dwelling, a large amount of dwellings will not be regarded as feasible options. Therefore we decide to make a pre-selection on which we actually estimate the model on. This is done as follows. According to the household's characteristics a number of constraints can be derived. These constraints can be divided into two subgroups, namely aspects of the dwelling and of the location, respectively the tenure type and price range of the vacant dwelling, and the migration and commuting distance. These last two distances primarily build up the spatial network of a household (Walmsley & Lewis, 1993). Of course, the number of constraints can be extended, by taking along other information on the moving household, e.g. like the migration reason.

The algorithm that is used to generate the considered choice set has yet to be determined. Nevertheless, several researches have been conducted that focus on choice set generation in discrete choice modelling in general (Swait, 2000) and for multimodal route choice in particular (Fiorenzo-Catalano et al., 2003). Also the previously discussed elimination-by-aspects method could be beneficial, since it provides a method to remove a number of alternatives from the total amount of available alternatives based on the preferences of the decision maker. Within this context, it is important to realise that for an explanatory model the alternatives in a choice set need to have a considerable amount of variation, otherwise the model estimation could give unexpected and false results (Vam der Waerden et al., 2004).

Of course the choice set has to be composed of actual supply that was available in the period the household was searching. This means that in an ideal situation, the researcher should have the list of alternatives from which the household has chosen from. The dataset from which the (revealed) moves are extracted, however, does not give this information. How this issue is handled in this research is discussed in the section “Data to use”.

#### *Disaggregated choice model*

The final step of the theoretical model is the actual discrete choice model, based on the Random Utility Theory. This theory is capable of simulating complex choice processes by regarding the attributes of the alternative and the decision maker. By estimating such a model, more insight is gained on the influence that certain attributes have on the choice process and the trade-offs a household makes when choosing for a dwelling.

The previous paragraph already stated that the individual characteristics of a household are important when composing the choice set. Same or other issues, like the household type, workplace(s) and income, also affect the choice behaviour. This information is only available at a low level of decision unit, namely the household itself. This means that we cannot work with aggregated groups of household, of which only the common features are known.

As stated before, there are many different modelling techniques to study discrete choices. Following McFadden (1978), we could try to build a Nested Logit model. This

technique has the advantage that is able to incorporate different levels of decision making, without conflicting with the strict properties of the Logit Theory. Therefore it is suitable for residential choice modelling, since this process has several choice levels, namely the choice for the region, the choice for the neighbourhood/location and the choice for the dwelling itself. A Mixed Logit approach can also be applied. This model can examine the heterogeneity of household choice behaviour through random coefficients specifications. The decision which modelling technique will be used in the final version of the model is made along the research.

#### *Accessibility in the model*

In all the mentioned steps of the model accessibility is incorporated, sometimes stronger than other. To understand the influence of accessibility on the residential choice process, we will try to distillate the importance of accessibility. This means that we try to filter out the impact of other location factors.

In this context it is important to acknowledge the difference between objective and subjective accessibility. The first is equal for every (type of) person on a certain location, e.g. the number of jobs available, the distance to the nearest train station, etc. This type of accessibility measures, as can be seen from the literature, turns out to be weak explaining variables. This is probably caused by the fact that the best, objective accessible (urban) areas like CBD's and locations near railway stations are often the most expensive ones, due to a high demand by urban activities. Moreover, these areas are not very attractive for residential urban areas, since they are more crowded, more polluted and not optimally designed to live in. This explains why sometimes accessibility is estimated as a negative explanatory variable.

When we look at subjective measures, we notice a strong relationship with the personal network of daily and weekly activities. This is best represented by the influence of the migration distance and commuting time on the migrations, as we will see in the next section of this paper. Given that the budget of a household for living is usually set (and optimally used), this household can make the decision whether to choose for a smaller apartment downtown or a larger semidetached house in the suburbs, i.e. a more versus a less accessible location. In terms of subjective accessibility, as the concentration of jobs

is still predominantly in the CBD's, the majority of the households will decide either to commute and live in a larger house, or to live small closer to the workplace.

Of course, the subjective social network brings along other activities as well, that can be represented by more general accessibility measures. The importance of these accessibilities, however, can be assumed to differ per household type. For example, a younger couple without children are more attracted to a downtown area, where many commercial services are situated, whilst a family with younger kids are looking for a place with a primary school and children day-care centre nearby.

In the sections to come, we will discuss in more detail how the subjective accessibility measures can be incorporated in a discrete choice model. First we will discuss the data we are using in this research.

## **Data to use**

The most important data source is the Housing Demand Survey (in Dutch: Het Woningbehoefte Onderzoek; WBO). This is a large survey which is kept every two years under a respectable amount of households. The last edition (WBO2002) exists of over 100.000 interviews, representing an even sample of the Dutch population. In these interviews people were asked about their future housing wishes and former moving behaviour along with questions on household characteristics like age, income, education, labour situation, etc. Also other issues come across like mobility behaviour and leisure activities.

The supply of vacant dwellings from which the households choose, is only available at an annual base from the SYSWOV database (Housing Supply System, in Dutch: Systeem Woningvoorraadgegevens). From this record a quarterly supply can be generated. How this is done will be presented in future papers.

The mobility behaviour is monitored by the Dutch Mobility Survey (in Dutch: Onderzoek Verplaatsingsgedrag; OVG). For this survey 140.000 persons from 60.000 households were asked to fill in a week diary on their movements. This resource could supply the information on mobility preference that is needed for this research. Finally,

the factor and cluster analyses to distillate the destination groups are carried out on the WBO and/or OVG analysis.

## **Migration distance and commuting time in the choice model**

When discussing the theoretical model, it was brought forward that taking along subjective accessibility measures could be beneficial in modelling the residential choice behaviour of households. In this section we would like to make a first attempt by exploring the influence of the migration distance and commuting time of the head of the household. To do so, we will first discuss shortly the migration data and the migration distance and commuting time. Then we derive two distance decay functions. Eventually, we compose a Logit-formula where both functions are combined.

### *Observed moves in the WBO2002*

As mentioned when we discussed the data, in the National Housing Survey (WBO2002) over 100.000 people were questioned. From these around 11.500 people were moved in the past two years (2000-2002). Finally, almost 8.000 of these movers also had a working place. The level of detail of the information on the current and previous residential location is a four digit postal zone (see figure 2). For the work location only the town is known. The sizes of these towns vary from large cities (e.g. Amsterdam) to small villages.





**Figure 2: Four-digit postal zones**

To analyse the migration distance and commuting time of the movers, we added a travel time to the moving and commuting relations. For the commuting travel time we used congested, morning peak travel times of the National Model System (in Dutch: Landelijk Model System, LMS), a renowned transport in the Netherlands. The migration distance is calculated with off-peak travel times, representing the time for social activities, which are usually carried out off-peak. Table 1 gives some statistical figures of the migration distance, the current commuting time and the decrease in commuting time due to the move.

**Tabel 1: Statistical figures migrations WBO2002.**

|                     |    | Migration distance (min.) | Commuting distance (min.) | Decrease comm. distance (min.) |
|---------------------|----|---------------------------|---------------------------|--------------------------------|
| Mean                |    | 18,9                      | 26.5                      | 5.9                            |
| Standard deviation  |    | 28,4                      | 26.2                      | 27.9                           |
| Percentiles         | 50 | 8.47                      | 18.14                     | 0,0                            |
|                     | 85 | 33.06                     | 48.98                     | 11,96                          |
|                     | 95 | 83.63                     | 72.84                     | 60.81                          |
| Number observations |    | 11652                     | 7802                      | 7783                           |

From these numbers it can be seen that a substantial part of the moves take place on a fairly short distance: over half of them are within 10 minutes, and 85 percent under 33 minutes. As for the commuting time, people are more flexible. The relation between the median and the standard deviation also shows the skewed distribution of the migration distance and commuting time, something that is known from the literature.

When we look at the cross table 2 with we see that, as expected, people in general have an aversion against both migration distance and commuting time, the first being stronger than the second. That is, people tend to move to a location close to the old dwelling, while keeping the commuting distance within a certain distance.

**Table 2: Percentage share moves to migration distance and commuting time.**


| Commuting time (min.) | Migration distance (min.) |              |              |              |              |             |             |             |              |
|-----------------------|---------------------------|--------------|--------------|--------------|--------------|-------------|-------------|-------------|--------------|
|                       |                           | 0 – 5        | 5 – 10       | 10 – 20      | 20 – 40      | 40 – 80     | 80 – 160    | > 160       | Total        |
|                       | 0 – 10                    | 12.5%        | 7.5%         | 4.4%         | 1.8%         | 1.4%        | 1.0%        | 0.2%        | <b>28.8%</b> |
|                       | 10 – 20                   | 8.3%         | 5.2%         | 6.6%         | 2.2%         | 1.6%        | 1.0%        | 0.1%        | <b>24.9%</b> |
|                       | 20 – 30                   | 4.8%         | 2.5%         | 3.5%         | 2.0%         | 0.9%        | 0.8%        | 0.0%        | <b>14.5%</b> |
|                       | 30 – 45                   | 4.3%         | 2.9%         | 2.9%         | 2.8%         | 1.2%        | 0.5%        | 0.0%        | <b>14.7%</b> |
|                       | 45 – 60                   | 2.2%         | 2.0%         | 2.0%         | 1.2%         | 1.1%        | 0.3%        | 0.0%        | <b>8.8%</b>  |
|                       | 60 – 90                   | 1.3%         | 1.0%         | 0.9%         | 0.7%         | 1.0%        | 0.3%        | 0.0%        | <b>5.2%</b>  |
|                       | > 90                      | 1.2%         | 0.6%         | 0.3%         | 0.3%         | 0.3%        | 0.5%        | 0.0%        | <b>3.2%</b>  |
|                       | Total                     | <b>34.6%</b> | <b>21.6%</b> | <b>20.7%</b> | <b>10.9%</b> | <b>7.5%</b> | <b>4.3%</b> | <b>0.4%</b> |              |

*sum = 74.2%*

On the other hand, table 3 shows us that, when a household decreases a (large) commuting distance, this normally leads to a larger migration distance. This implies that it leaves the old residential location to settle somewhere else near the job place.

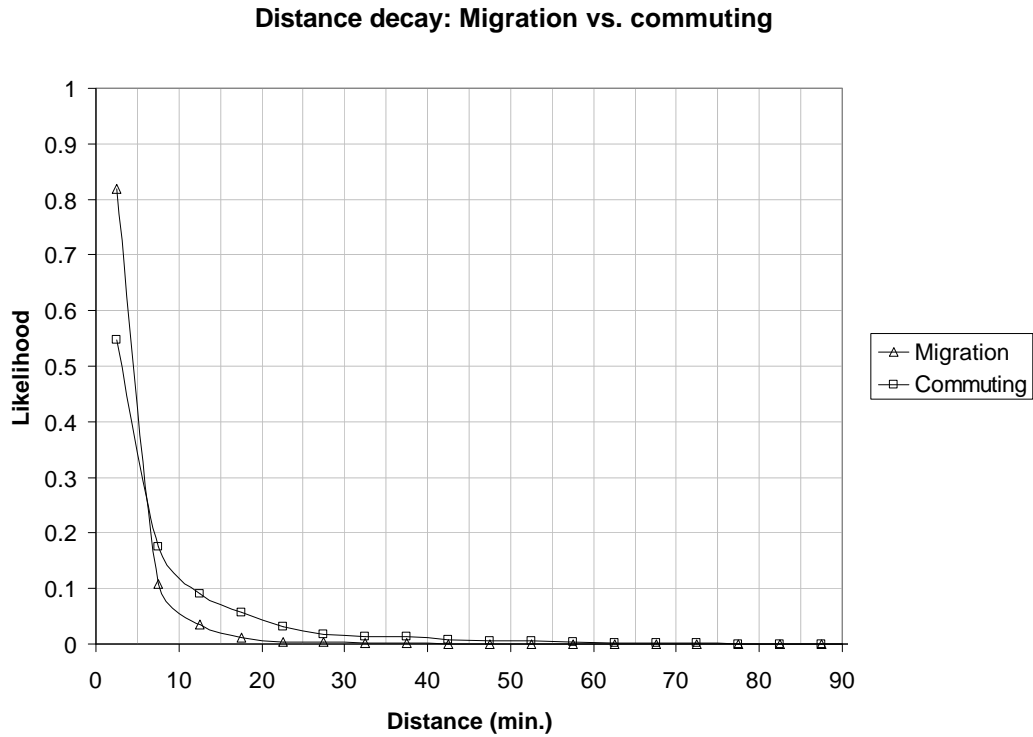
**Table 3: Percentage share moves to migration distance and decrease in commuting time.**

| Decrease in commuting time (min.) | Migration distance (min.) |       |        |         |         |         |          |       |
|-----------------------------------|---------------------------|-------|--------|---------|---------|---------|----------|-------|
|                                   |                           | 0 – 5 | 5 – 10 | 10 – 20 | 20 – 40 | 40 – 80 | 80 - 160 | > 160 |
|                                   | < -90                     |       |        |         |         |         |          |       |
|                                   | -90 – -60                 |       |        |         |         | 0.3%    | 0.2%     | 0.0%  |
|                                   | -60 – -45                 |       |        |         | 0.0%    | 0.5%    | 0.0%     |       |
|                                   | -45 – -30                 |       |        | 0.1%    | 0.8%    | 0.7%    | 0.0%     |       |
|                                   | -30 – -20                 |       |        | 0.3%    | 1.2%    | 0.2%    | 0.0%     |       |
|                                   | -20 – -10                 | 0.0%  | 0.1%   | 2.2%    | 1.5%    | 0.2%    | 0.0%     |       |
|                                   | -10 – 0                   | 3.3%  | 10.9%  | 7.8%    | 1.3%    | 0.2%    | 0.1%     |       |
|                                   | 0                         | 28.2% | 0.1%   | 0.0%    |         | 0.0%    |          |       |
|                                   | 0 – 10                    | 3.2%  | 10.2%  | 8.0%    | 1.4%    | 0.3%    | 0.0%     |       |
|                                   | 10 – 20                   |       | 0.0%   | 2.2%    | 2.0%    | 0.4%    | 0.1%     |       |
|                                   | 20 – 30                   |       |        | 0.2%    | 1.8%    | 0.5%    | 0.1%     |       |
|                                   | 30 – 45                   |       |        | 0.0%    | 0.9%    | 1.1%    | 0.1%     |       |
|                                   | 45 – 60                   |       |        |         | 0.1%    | 1.8%    | 0.1%     | 0.0%  |
|                                   | 60 – 90                   |       |        |         |         | 1.3%    | 1.2%     | 0.0%  |
|                                   | > 90                      |       |        |         |         | 0.1%    | 2.4%     | 0.4%  |

 : sum = 76.0%

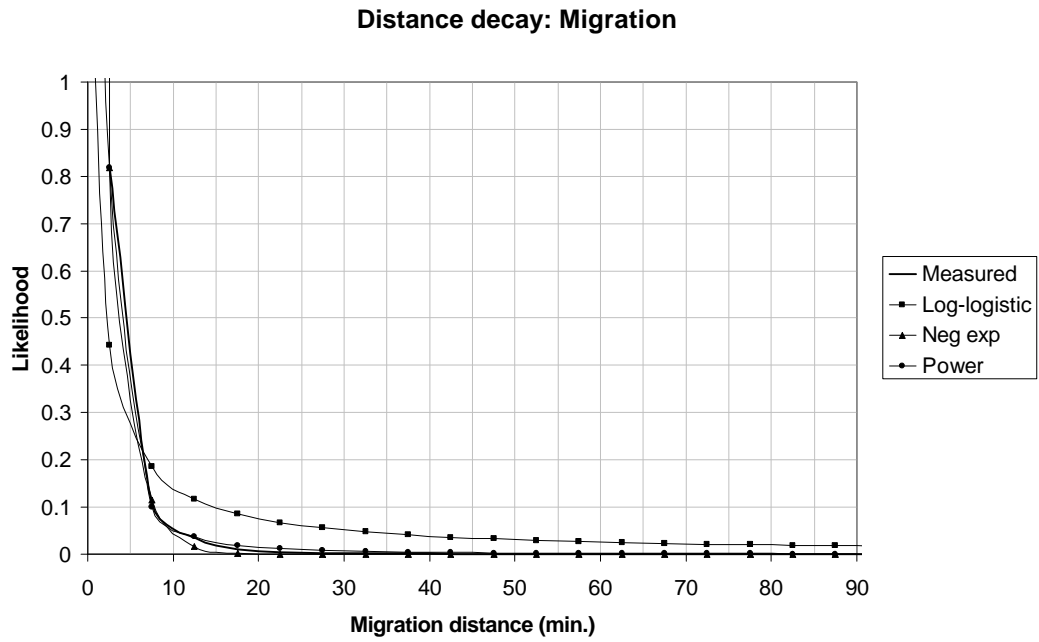
#### *Estimating the independent influence of the migration distance and commuting distance*

Tables 2 and 3 show that the migration distance and the commuting time have a simultaneous influence on the residential location choice. Analogous to transport studies, this influence can be described as a distance decay function where the chance of a trip is subject to the distance of the trip. In this context: the chance that a household settles on a location is subject to the migration distance and the (new) commuting time. Figure 2 shows the distance decay functions of both. The chance that a move is made is here calculated as the number of (observed) moves per time class of five minutes, divided by the number of possible moves).

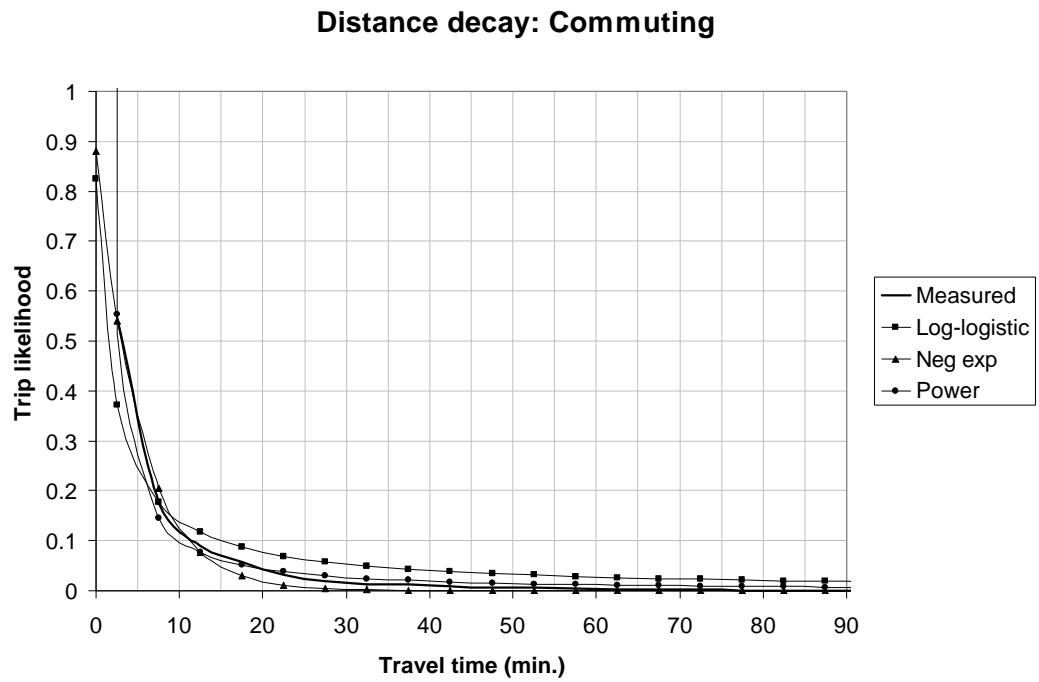


**Figure 3: Distance decay functions for migration distance and commuting time.**

In an overview of distance decay functions, given by Geurs and Ritsema van Eck (2001), a distance decay function can be described by several functions, namely: a negative power, a negative exponential, a log-logistic and a modified normal (Gaussian). Considering the shapes of the measured distance decay functions, we decided to investigate which of the first three functions fits the data best. These estimations are shown in figures 4 and 5.



**Figure 4: Distance decay functions for migration.**



**Figure 5: Distance decay functions for commuting.**

When we look at the graphs of figures 5 and 6, we see that the estimated power function approximates the measured migrations and commuting distances best. This power function has the following formulation:

$$F(d_{ij}) = \mathbf{b} \cdot d_{ij}^{-\mathbf{a}} \quad (1)$$

with  $\mathbf{a}$  and  $\mathbf{b}$  as the function parameters and  $d_{ij}$  as the distance between point  $i$  and  $j$ .

The estimations of the function gave the following parameters:

**Table 4: Estimated parameters power function.**

| Parameter | $\mathbf{a}$ | $\mathbf{b}$ |
|-----------|--------------|--------------|
| Migration | 1.912        | 4.724        |
| Commuting | 1.695        | 1.221        |

Fotheringham and O’Kelly (1989) support the usage of a power function for long-distance migrations, but here it is proven that it also fits best for shorter distances.

However, these power-functions (with these parameters) cannot be used to calculate the chance that a residential location is chosen. After all, the location choice is a simultaneous choice in which both relations play a part and are non-independent. That is to say, the two estimated functions should not be “simply” added up (or multiplied) to retrieve the chance; they have to be estimated simultaneously. To do so, we have chosen to formulate a Logit function that combines both distance decay functions, as can be seen in the next section.

*Derivation of the Logit formula.*

In this last section we will deduct a Logit formulation that can be used to estimate the specific influence of the migration distance and commuting time. This derivation can also be extended with more location- and household specific variables.

The general form of the Logit-function for the chance that an option  $i$  is chosen from a subset  $k$  of all alternatives  $c$  is:

$$P_c(i) = \frac{e^{V_i}}{\sum_{k \in c} e^{V_k}} \quad (2)$$

with for the utility of  $i$ :

$$V_i = \mathbf{q}_1 \cdot v_1 + \dots + \mathbf{q}_n \cdot v_n \quad (3)$$

At first, only the migration distance and commuting time will be included. According to Nijkamp and Reggiani (1992), the logarithm of the distance decay function represents the (dis-)utility of a trip or move, so we can write:

$$V_i = \mathbf{q}_{oi} \cdot \ln F(d_{oi}) + \mathbf{q}_{iw} \cdot \ln F(d_{iw}) \quad (4)$$

with:  $o$  = index location old dwelling  
 $w$  = index location work place

When we combine this formula with the earlier mentioned power functions for the distance decay, (4) can be transformed into (5), where  $O$  and  $W$  mark the parameters regarding respectively migration and commuting.

$$V_i = \mathbf{q}^O \cdot \ln \mathbf{b}^O \cdot d_{oi}^{-a^O} + \mathbf{q}^W \cdot \ln \mathbf{b}^W \cdot d_{iw}^{-a^W} \quad (5)$$

This can be rewritten into:

$$V_i = \mathbf{m}^O \cdot \ln d_{oi} + \mathbf{m}^W \cdot \ln d_{iw} + \mathbf{n} \quad (6)$$

### *Next research steps*

The choice set generation will be the first step necessary to estimate the derived Logit model. This choice set will be constructed by combining the current residential and working location. Due to these both dominant, spatial relations, the search area is assumed to have the form of an ellipse.

To begin with, we will estimate a model with merely the migration distance and commuting time. During this procedure other specifications for the distance decay functions, like the log-logistic, are tried. After all, when estimated simultaneously, they could turn out to be a better fit on the empirical data.

Subsequently, the Logit model can be extended with more variables regarding the characteristics of the dwelling, location/neighbourhood and household. Also possibilities to experiment with the formulation of the discrete choice model are not excluded. For example, it could be beneficial to try a nested Logit approach, in order to nest the characteristics of the location and the dwelling.

Finally, we strive for a model as discussed in the previous section on the theoretical choice model.

## **Resume & Conclusion**

We have presented an approach to model the residential choice behaviour of households in integrated land-use and transportation models. Within this approach special attention goes out to the influence of accessibility on this behaviour. From the literature it shows that many (empirical) researches were not able to measure this influence. This is probably due to the fact that accessibility, when incorporated in the analysis, is overshadowed in importance by many other residential choice factors. Only commuting (time) and the migration distance seem to be significant, measurable variables. We will try to include these into our model. Furthermore we have chosen to follow the Random Utility Theory to explain the behaviour, since this comes closest to the perception of a real life choice.

The theoretical model presented in this paper introduces some new approaches to cope with this problem. The first one is the usage of specific groups. These groups have a



certain, common preference for the type of dwelling, living environment and mobility services. Following this preference more “tailor made” models can be developed and estimated. The second proposed improvement on the model approach is the usage of systematic choice sets. After it is determined to what destination group a household belongs to, a large amount of alternatives can be dropped because they are not acceptable for this type of household. When composing the choice set other, more personal issues can be taken along as well. These are aspects that concern the income, number of people, age and the personal network of activities of a household (work, relatives, education, leisure, etc.). Finally this disaggregated method is continued in the discrete choice model.

As for the ways that accessibility can be built into the model, we tend to make a distinction between subjective and objective accessibility. The latter often turns out to have a negative relation with residential choice. After all the most accessible locations for example in terms of the number of jobs and inhabitants within 30 minutes travel time, are not the most attractive ones to live in and are often more expensive due to higher demands by commercial urban functions. On the other hand, subjective measures like the migration distance, commuting distance and the proximity of household type specific services, matter to the household itself when it makes a decision where to settle.

The first step to incorporate subjective accessibility is made in the last part of the paper. Here we have derived a model formulation wherein the migration distance and commuting time are integrated. Prior to that we explored the best functions to express the distance decay relation of both relations, which turned out to be power functions.

The paper was rounded up with some future research steps, from which the designing of the choice set and the first estimations of the Logit model are the most crucial at this moment. We expect to have the first results during the summer of 2004.

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